

OSTROLENK, FABER, GERB & SOFFEN, LLP

Attorneys at Law

1180 Avenue of the Americas
New York, New York 10036-8403

(212) 382-0700

Telex
23 6925

Facsimile
(212) 382-0888

Cable
Ostrofaber NewYork

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OFGS File No. : P/1336-101
Inventor : Martin BICHSEL
Title : METHOD FOR THE COMPRESSION OF RECORDINGS OF AMBIENT
NOISE, METHOD FOR THE DETECTION OF PROGRAM ELEMENTS
THEREIN, AND DEVICE THEREFOR
Assignee : Liechti AG

Enclosed herewith please find the following documents in the above-identified application for United States Letters Patent:

30 Pages of Specification including Abstract and Claims
29 Numbered Claims Calculated as 29 Claims for Fee Purposes
3 Sheets of Drawing Containing Figures 1 to 4.
X Declaration and Power of Attorney
X Priority is Claimed under 35 U.S.C. §119:
Convention Date June 23, 1997 for Switzerland Appln. S.N. 1997 1520/97
X Certified Priority Application
X Form PTO-1449, International Search Report, and 5 references
X Assignment
X Return-Addressed Post Card

OFGS Check No. 77081, which includes the fee of \$1,028.00, calculated as follows:

Basic Filing Fee:	\$ 790.00
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Date of Signature

Robert C. Faber
Robert C. Faber
Registration No.: 24,322
OSTROLENK, FABER, GERB & SOFFEN, LLP
1180 Avenue of the Americas
New York, New York 10036-8403
Telephone: (212) 382-0700

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**Method for the Compression of Recordings of Ambient Noise,
Method for the Detection of Program Elements therein, and
Device therefor**

5 Background of the Invention

The present invention refers to a method for the compression of an electric audio signal which is produced in the process of recording the ambient noise by means of an
10 electroacoustic transducer, more particularly a microphone. Furthermore, the invention also refers to a device for carrying out the method.

In the field of audience research, which also comprises the
15 acoustic perception of other media such as e.g. television, recordings of the acoustic environment of a panelist in a survey are used, i.e. the so-called hearing samples. The storage of these hearing samples on portable magnetic tape recorders is disclosed in US 5,023,929. The inconvenient of
20 this method is that the tape recorder is relatively large although it is intended to be permanently carried by the participant.

Consequently, it would be preferable to integrate the
25 hearing sample recorder or monitor in an appliance which is normally worn or at least less visible. Such a possibility, namely the integration into a wristwatch, is mentioned in EP-A-0 598 682 to the applicant, this application being hereby incorporated into the present specification.

30 However, the mentioned application does not indicate how the hearing samples can be stored in the extremely narrow space and with the very limited energy available in a wristwatch or a similarly inconspicuous appliance over a considerable
35 period of time such as at least a week. Although the

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specification mentions the need of compression procedures,
known methods only are indicated.

Summary of the Invention

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It is therefore an object of the present invention to
provide a method for the compression of hearing samples
which in particular allows to obtain a high compression with
minimal efforts with the safe recognition of program
10 elements being essentially conserved.

This object is attained by a method for the compression of
an electric audio signal which is produced in the process of
recording the ambient noise by means of an electroacoustic
15 transducer, more particularly a microphone, wherein
- the amplitude of said audio signal or of a derived digital
or analog signal is normalized to a first predetermined
range D;
- said audio signal is mapped in the form of a non-linear
20 mapping onto a second predetermined range of values W in
order to obtain an emphasis of sensitive values; and
- the result is stored in an electronic memory in a digital
form.

The further claims indicate preferred embodiments, devices
25 for carrying out the method, and applications.

In the following, the same terminology as in EP-A-0 598 682
will be used. A hearing sample is basically a recording of
the ambient noise e.g. by means of a microphone. In order
30 to simplify the storage as well as the transmission to the
evaluating center, however, it is preferred to have a
succession of short recordings of the ambient noise or
hearing samples which are recorded at certain times.
Preferably, the recordings are effected at regular intervals
35 of e.g. 1 minute, and have a constant duration of the order

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of, for example, 4 seconds, the information of the time of the recordings being stored together with the hearing sample.

5 According to the invention, the hearing samples are finally stored in an electronic memory in a digitized form. According to the invention, in order to reduce the amount of data to be stored, a normalization of the hearing samples in their original form or in a derived form (filtered, limited
10 to selective frequency bands, digital or analog, etc.) to a predetermined range (of values or amplitudes) D and a subsequent nonlinear transformation on a second range W is effected whose result, which is limited to the range W, is then stored in an electronic memory. The range W may be
15 smaller or equal to D, but it is preferably substantially smaller.

Essentially, the non-linear transformation serves the purpose of amplifying sensitive areas of range D in such a
20 manner that the more significant information provided by a signal whose value is comprised in such a sub-range of D is emphasized in the result, i.e. its resolution is increased.

Preferred further developments of the invention are as
25 follows:

A: The nonlinear mapping is characterized by a decreasing slope dW/dD for increasing values in D, e.g. similar to the logarithmic function. Essentially, the range
30 of small values in D is thereby mapped onto a relatively larger range in W and thus emphasized, whereas relatively large values in D are mapped on a relatively small range in W only, i.e. their significance is attenuated.

35

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B: The hearing samples are digitized immediately after recording (e.g. by a microphone) and analog processing (amplification; coarse filtering in preparation of the analog-digital conversion, etc.), resulting in a succession of numeric values. Each numeric value represents e.g. the momentary loudness of the ambient noise at a determined time.

Further processing is effected digitally by digital circuits, program controlled processors, or combinations thereof.

C: The amplitude or loudness values are transformed into energy values e.g. by squaring. The energy values are submitted to a low pass filtering and subsequently differentiated, the differentiation preferably being simulated by a difference calculus. The resulting energy variation values indicate the variation of the low-frequency proportion of the energy content in time.

D: The group of the energy variation values of a hearing sample, or only a part thereof, is normalized with respect to the maximum value of the values within the (partial) group. For this purpose, the maximum value is determined and all values of the group are divided by this maximum value. Simultaneously, the normalized values are mapped on a given range of numbers corresponding to the range D, e.g. the numbers between -128 and +127, so that the following arithmetic operations involve only integers. The number of values in these numerical ranges D is therefore preferably equal to powers of 2 (in the example: $256 = 2^8$ values) which are particularly advantageous in the case of binary digital processing. In order to

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perform this combination of normalizing and of
imaging, the values of a group are multiplied by a
factor which results from the division of the limit of
the numeric range (i.e. 128 in the example) by the
maximum value within the group.

E: The results of this step are again mapped on a
further, smaller range of values W, e.g. the numerical
range from 0 to 15 comprising $2^4 = 16$ numbers. On
account of the fixed and relatively small number of
values of the input data of this step, a so-called
look-up table may be used for this second mapping.

Overall, it follows from the preceding that each
numerical value of the hearing samples is reduced to a
relatively short binary number (of 4 bits in the
example).

F: Further optimizations are applied, such as e.g. taking
the mean value of a plurality of values, only the mean
value being further used. This also results in an
important reduction of the number of values to be
processed. On the digital level, such a filtering is
simulated by a convolution.

G: Before or after being digitized at the input, the
hearing sample is split into frequency bands or band
signals. In a known manner, digital filterings may be
effected by convolutions, and since the preferred
convolutions represent low pass filterings, it is
preferable to transmit less values to the following
processing stages than are used for the convolution,
preferably only one respective value.

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Brief Description of the Drawings

The invention will be explained in more detail hereinafter by means of an exemplary embodiment and with reference to
5 figures.

Fig. 1 shows a block diagram of a monitor according to the invention;

10 Fig. 2 shows the division into frequency bands;

Fig. 3 shows the conversion into energy values and the differentiation;

15 Fig. 4 shows the "normalizing quantization".

Detailed Description of the Invention

Fig. 1 shows a block diagram of a monitor 1. It may e.g. be
20 intended to be integrated in a wristwatch, which is why monitor 1 comprises a clock circuit 2 which also serves as a time base for the signal processing, as well as a (liquid crystal) display 3. Commercially available components may be used for circuit 2 and display 3. A precise clock signal
25 is generated by a quartz 4 in conjunction with an oscillator circuit which is integrated in clock circuit 2. Since a highly precise timing is required for the synchronization of the hearing samples to the comparative samples, a temperature compensation is provided in addition. The
30 latter comprises a temperature sensor 5 which is connected to the clock circuit by means of an interface circuit 6. Interface circuit 6 essentially comprises an A/D converter.

Another important element for the monitor function is
35 wearing detector 7. It may essentially consist of a sensor

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area on the wristwatch which detects the contact with the skin of the wearer. In the example, wearing sensor 7 is connected to clock circuit 2 by means of an interface circuit 8, which implies that the clock circuit is capable of providing the time indications with an additional mark from the wearing sensor. It is also conceivable to directly connect the wearing sensor to the proper monitor circuit, e.g. to digital signal processor 9.

10 The clock signals which are required for the signal processing, in particular for signal processor 9, are derived from the time base clock, which is taken from a connection 10 of quartz 4, by a PLL (phase locked loop) circuit 11. The time and the date as well as the mark from
15 the wearing sensor, as the case may be, are transmitted from clock circuit 2 to digital signal processor 9 by a serial data connection 12.

The hearing samples are stored in a flash memory. It is an
20 important advantage with respect to the present application that flash memories are capable of storing data in a non-volatile manner and of deleting them again without the need of particular measures. A bus 14 allowing to transmit both data and addresses serves to connect flash memory 13 and
25 signal processor 9.

A multiplexer 16 is connected by a second serial connection. Depending on the operational condition, the multiplexer connects signal processor 9 to the recording unit of the
30 hearing samples or to interface circuit 17 by means of which the data exchange with the evaluating center is effected.

The recording unit consists of a microphone 18 and a following A/D converter unit 19 which in addition to the
35 proper A/D converter may comprise amplifiers, filters (anti-

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aliasing filters) and other usual measures in order to ensure a digital signal which represents the recording by the microphone as correctly as possible.

- 5 Power supply 20 may be a battery (lithium cell) or the like. An accumulator in conjunction with a contactless charging system by means of electromagnetic induction or a photo cell is also conceivable.
- 10 To ensure the connection to the exterior, more particularly for the transmission of data to the evaluating center, monitor 1 is provided with a bidirectional data connection 21, a reset input 22, a synchronization input 23, and a power supply terminal 24. The presence of a power supply at
- 15 terminal 24 is also used to make the monitor change to the data transmission mode. For example, the monitor may be connected to a base station which establishes a connection to an evaluating center e.g. by telephone. Another possibility consists in mailing the monitor to the center
- 20 where it is connected to a reading station. On this occasion, besides the data transmission, a synchronization of clock circuit 2 to the clock of the center may be effected, as previously described in EP-A-0 598 682.
- 25 As shown in the illustration, the hearing sample processing unit including signal processor 9 and the necessary accessory components (multiplexer 16, memory 13, clock generator consisting of PLL circuit 11 and quartz 10, etc.) may be composed of discrete components. In order to be
- 30 incorporated in a wristwatch, however, the functions must be integrated in as few components as possible, which may result in a single application specific circuit 30 in the extreme case. For example, signal processors of the TMS 320C5x series (manufacturer: Texas Instruments) may be used,
- 35 in which multiplexer 16 is already contained, inter alia,

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and Flash RAMs of the type AM29LV800 (manufacturer: Amdahl) having a capacity of 8 MBit. Such a memory capacity and the application of the compression method for hearing sample data according to the invention as described hereinafter
5 allow to attain an uninterrupted operation of the monitor for approx. 7 days.

In view of energy consumption, it is advantageous if the hearing sample processing unit, more particularly signal
10 processor 9, is only periodically switched on. If e.g. one hearing sample per minute is taken, it is sufficient according to the processing method of the present invention to switch on the power supply of the signal processor for some seconds (less than 5, e.g. 4 seconds) only. For this
15 purpose, the power supply receives an on-signal 25 from clock circuit 2 during whose presence the hearing sample processing unit is supplied with current. A further reduction of the energy consumption is obtained by the fact that flash memory 13 is only supplied with the current
20 required for the storing process for a short time, 3 milliseconds at the end of each processed hearing sample recording being sufficient in the case of the above-suggested type. The signal 26 required therefor is generated by signal processor 9. The program controlling
25 the signal processor is contained in a separate program memory which may be integrated in the signal processor itself, so that the hearing sample processing operation can also be performed while flash memory 13 is off.

30 Hereinafter, the method for the processing of the hearing samples is described. After the recording of the ambient noise (microphone 18) and its analog-digital conversion according to known principles (A/D converter unit 19), a splitting into e.g. six frequency bands is performed (Fig.
35 2) which is effected by a hierarchical arrangement of low

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passes 30 - 35. The required high pass associated to each low pass is realized by a subtraction 36 - 41 of the output signals 42 - 47 from the respective input signals 48 - 53 of the low passes, the subtraction being effected by an addition of the inverted output signals 42 - 47 of low passes 30 - 35.

Low pass filters 30 to 35 are realized by a 19-digit convolution:

$$y_j = \sum_{i=0}^{18} a_i x_{j-i} \quad (1)$$

where

j : time index
 y_j : output value of the low pass filtering at the time j ;
 x_j : input value for low pass filtering at the time j ;
 a_i : coefficient of the convolution sequence;
 $a_0 \dots a_{18}$: [0.03, 0.0, -0.05, 0.0, 0.06, 0.0, -0.11, 0.0, 0.32, 0.50, 0.32, 0.0, -0.11, 0.0, 0.06, 0.0, -0.05, 0.0, 0.03]

In the course of the splitting into the frequency bands or band signals (54), a first data reduction is already effected in that only every second value out of each sequence of output values of the high and low pass filterings is transmitted to the following low resp. high pass stage or to outputs 54 by the switches 55. Overall, this already allows to obtain a reduction of the data volume to 1/8. With the division into six bands used in the example, this results in a slight overcompensation of the accompanying increase of the data volume by a factor six.

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A criterion for the design of the filters is that one band may contain the contents of every other band in a clearly attenuated form at the most. A reduction to the half at least may be considered as clearly attenuated. Ideally, the
 5 bands only contain residual portions of directly adjacent bands, portions which are near or below the resolution of the digital numerical representation even. In the preferred digital realization, this aim is attained by low pass filtering (convolution) and subsequent subtraction of the
 10 filtered proportion from the input signal of the low pass filter.

The treatment of the band signals 54 resulting from the division into bands is identical in each band, Figs. 3 and 4
 15 showing the processing of only one band 56 in a representative manner.

Input signal 56, which is identical to output signal 54, is first squared in that it is supplied to the two inputs of a
 20 multiplier 57 in parallel. Except a proportionality factor, this squaring corresponds to a calculation of the energy content of the proportion of the ambient noise which is represented by signal 56. Energy values 58 are subjected to a low pass filtering. This filtering is realized by means
 25 of a convolution over 48 values:

$$y_j^e = \sum_{i=0}^{47} b_i x_{j-i}^e \quad (2)$$

where

30

j : time index of the y^e and x^e values;
 x_j^e : energy value 58 at the time j;

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y_j^e : output signal of the low pass filter 59 at the
time j ;
 b_i : the coefficients of the convolution sequence,
wherein $b_0 = b_1 = \dots = b_{47} = 1.00$.

5

Of the output values of low pass filter 59, only every 48th value is forwarded to the following differentiation 61 by switch 60. Overall, here, a data reduction to 1/48 of the input data volume is obtained by the formation of a mean
10 value.

In differentiator 61, each incoming value is delayed by a time unit in delay unit 62. Delay unit 62 may e.g. be a FIFO waiting queue having a length of 1.

15

In adder 63, the undelayed values are added to the inverted, delayed values, so that the values of the differences between two successive input values of the differentiator 61 are available at the output 64. The differences refer to a
20 determined, constant and known time shift which is given by the time units, and consequently represent an approximation of the derivative with respect to time.

The energy difference values 64 are subjected to the
25 normalized quantization. On one hand, according to Fig. 4, the absolute value of the energy difference values is formed in absolute value unit 65. These absolute values are supplied to a maximum value detector 66 at the output 67 of which the greater one of the values supplied to its inputs
30 68 appears. Since the output signal from output 67 is fed back to one of the two inputs 68 by a single-stage delay circuit 69, the maximum value of all values received by absolute value unit 65 is formed at output 67. The maximum values pass through another switch 70 which only transmits
35 every 32nd value, i.e. a value which is the greatest within

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a hearing sample (the hearing sample duration used in this embodiment results in 32 energy difference values 64 per hearing sample in each frequency band).

5 In a reciprocal-computing and multiplication unit 71, the number 128 ($= 2^7$) is divided by the maximum value of the hearing sample and the result is supplied to an input 72 of a multiplier 73. The other input of multiplier 73 is then successively supplied with the energy difference values
10 64 among which the maximum value has been determined. For this purpose, the difference values 64 are temporarily stored in a FIFO buffer 75. The result of the multiplication in multiplier 73, whose values are comprised between -128 and +127, is converted by converter
15 76 into integers in the range D from 0 to 255, corresponding to a byte having 8 bits. These numbers are used as addresses in a look-up table (LUT) 77 where a number in the range W = 0 to 15, i.e. a four-digit binary number, is associated to each input value. The discrete mapping of 8-
20 bit numbers onto 4-bit numbers performed in LUT 77 is nonlinear and so designed that the resolution of small input numbers is finer than that of greater input values, i.e. that small input values are more emphasized. This may be referred to as a non-equidistant quantization.

25 The 4-bit values from output 78 are stored in flash memory 13 (Fig. 1).

The described normalized, non-equidistant quantization and
30 compression unit is provided for each band according to the illustration of Fig. 3, resulting in 4-bit values for a total of $32 \times 48 \times 8 = 12,288$ values per processing cycle which are recorded by the A/D converter at input 48 (Fig. 2). With an A/D conversion rate of 3,000 to 5,000
35 conversions per second, as provided by the currently

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available A/D converters of the lowest power consumption, this results in a hearing sample duration of approx. 2.5 to 4 s. With a supposed rate of one hearing sample per minute, the necessary memory capacity for the data amounts to $32 \times 6 \times 4 = 768$ bit/min or 1'105'920 bit/d. The indicated 8 Mbit memory thus allows to record approx. 7 days of uninterrupted operation of the monitor.

In view of a reduction of the required computing, all cited calculations are effected by integer or fixed point arithmetic unless especially indicated, in particular an exponential representation of floating point numbers is avoided. The number of bits used for the representation of a number essentially depends on the used processor and on the data length provided by the latter. The above-mentioned processor family TMS320C5x uses 16-bit arithmetic. The binary point for fixed point arithmetic is set in such a manner that the limited computing accuracy is optimally utilized in each processing step although the probability of a data overflow is extremely low. Therefore, the binary point is set differently in the different processing steps. In the preferred embodiment of the band division, the least significant bit represents the value 2^{-16} for the filter coefficients and the value 2^0 for the data values. Energy conversion and energy filtering are calculated by 32-bit integer arithmetic which is implemented as standard library function calls.

Prior to the storage in the flash memory or alternatively in the evaluating center, usual compression methods may be additionally applied which allow restoration of the original data in an identical form when decompressed.

In preparation of the recognition of the program elements which are possibly contained in the hearing samples, program

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samples are as exactly simultaneously as possible taken, e.g. directly at the broadcasting station, and stored. Prior to their comparison, the program samples are preferably subjected to the same processing and compression process as the hearing samples. This may be the case before the storage or only at the time of reading resp. playback of the stored program samples.

For the recognition, one of the usual correlation methods may be used. It is also possible to apply a coarse correlation using a fast computing procedure first and to perform a more precise and complicated correlation only if a sufficient probability of the presence of a given hearing sample has been found. In particular, such a preceding coarse correlation also provides a first coarse estimate of a subsisting minimal time shift between the hearing sample and the reference samples recorded at the station. In the more complex procedure, finer time shifts are analyzed and a more rugged comparison method is applied which takes account of the statistical distribution of the program signal and of interference signals.

Essentially, in the course of the evaluation, the simultaneous captured samples of each program as recorded each by a stationary unit are compared to the hearing samples of each monitor. An exemplary comparison method is illustrated in the following pseudocode which describes the correlation of a hearing sample of a monitor:

```
30 Decompress data of the monitor
    OptimumMatch := -1
```

```
FOR StationaryUnit := 1 TO NumberOfStationaryUnits DO
    Load digitized program samples which have been recorded at the same
35 time as the hearing samples of the monitor;
```


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```

Apply same preliminary processing as to hearing samples;
FOR TimeShift := 1 TO MaxTimeShift STEP Timestep DO
  {Takes account of running inaccuracies of the timers by a step size of
  Timestep}
5   Calculate matching coefficient c. with standard correlation for the
    actual time shift and assign result to the variable ActualMatch;
      IF (ActualMatch > OptimumMatch) DO
        OptimumMatch := ActualMatch;
        OptimumTimeShift := TimeShift;
10      OptimumStationaryUnit := Stationary Unit;
      ENDIF
    ENDFOR
  ENDFOR

15 IF (OptimumMatch > Threshold) DO
    RadioStation is recognized;
    The correct station is stored in the memory OptimumStationaryUnit
  ELSE
    None of the surveyed reference programs was heard at this time
20 ENDIF

```

In this procedure, only one of the radio programs registered
 in 'NumberOfStationaryUnits' is determined in the hearing
 sample of a monitor, namely the one which yields the highest
 25 probability (value of the variable 'OptimumMatch').

In particular, the optional, univocally reversible
 compression of the hearing samples processed according to
 the invention is reversed. This is followed by the
 30 initialization of 'OptimumMatch' to the lowest value which
 also indicates "no match", i.e. the wearer of the monitor
 has listened to none of the monitored programs.

The program samples of each stationary unit simultaneously
 35 recorded with the current hearing sample (loop "For

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StationaryUnit:= 1 to NumberOfStationaryUnits ... EndDo" are loaded and processed in the same manner as the hearing sample. Due to subsisting small time shifts between the hearing samples and the program samples, the following comparison is performed for a certain number 'MaxTimeShift' of assumed time shifts (loop "For TimeShift := 1 to MaxTimeShift ... Endfor"). The comparison is effected by a standard correlation of program and hearing sample data which are shifted forwards or backwards with respect to each other according to the 'TimeShift' variable. In order to always allow a full correlation over all values of the hearing sample, the program samples are therefore recorded over a longer period per sample, the beginning being additionally set earlier in time by the corresponding maximum time shift. Correspondingly, the length of the program sample is chosen in such a manner that the hearing sample is still completely contained in the program sample time even if the beginnings of the program sample and of the hearing sample are maximally displaced.

The normalized correlation is performed according to the following formula:

$$c_t = \frac{\sum_{i=1}^N (s_i m_{i-t})}{\sqrt{\sum_{i=1}^N (s_i)^2} \sqrt{\sum_{i=1}^N (m_{i-t})^2}} \quad (3)$$

where

t : time shift index (= 'TimeShift' in pseudocode);
 N : number of correlated values, generally equal to the number of values in a hearing sample;
 i : time index;
 s_i : hearing sample value at the time i;

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m_{i-t} : program sample value at the time i , displaced by
 t time steps;
 c_t : correlation value for the time shift t : $-1 \leq c_t \leq 1$.

5

The c_t values for different t values and program samples are compared, and the greatest c_t value overall is stored along with the indications of the conditions in which it has been recorded. These indications consist of the time shift, the
 10 stationary unit, i.e. the program, and of the correlation value c_t itself.

If the so determined greatest c_t value is superior to a predetermined threshold value, the corresponding program is
 15 considered to be contained in the hearing sample. If the threshold value is not attained, it is assumed that no one of the programs was heard.

Since the correlation must be performed correspondingly
 20 often due to the considerable scope of time shifts (t resp. TimeShift), a simplified alternative is conceivable where the time intervals are treated with a coarser graduation. For those c_t values which exceed a predetermined threshold, the correlation is repeated with a more rugged method while
 25 taking account of all detected time shifts.

A suitable rugged correlation is

$$r_t = \frac{\sum_{i=1}^N |s_i - a * m_{i-t}|}{\sum_{i=1}^N |s_i|} \quad (4)$$

30

where

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r_t : "rugged" correlation value;
 a : scaling factor which takes account of the
attenuation of the program signal with respect
to the hearing sample;

5 the remaining symbols corresponding to formula (3).

The procedure thus essentially uses absolute values both of
the deviation between the hearing sample and the scaled
program signal and of the hearing sample signal. The
10 scaling factor a is iteratively determined in such a manner
that the rugged correlation value r_t becomes minimal.
Compared to the normal correlation, large deviations are
less weighted in the rugged correlation, thus taking account
of statistical distributions of hearing sample values and of
15 program signal values and therefore resulting in better
recognition rates for real signals than the normal
correlation value c_t . In particular, individual hearing
samples with large deviations are less weighted.

20 Tests show that the described method not only eliminates or
at least strongly reduces known interference effects such as
secondary noise and time shifts but that damping (speakers,
transmission lines, general acoustic conditions) and echo as
well have only little influence on the recognition of a
25 program. It has been particularly surprising to find that
the program could often be detected in the hearing samples
even when the program element was inaudible. The
suppression of echo effects is attributed to the formation
of a temporal mean (filter 59), in particular, especially if
30 its time constant is chosen in such a manner as to be
greater than the echo times usually found in a normal
environment. A typically frequency-dependent (acoustic)
damping is compensated by the described suitable combination
of a division into frequency bands, a normalization to the
35 maximum value, and in taking into account of the damping by

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means of the scaling factor \underline{a} in the calculation of r_i or by the calculation mode of c_i .

Modifications of the exemplary embodiment within the scope
5 of the invention are apparent to those skilled in the art.

According to the technological development, different components (signal processors, memories, etc.) may be used. Alternatives are conceivable in particular for the flash
10 memory, e.g. battery-backed up CMOS memories. The criteria, especially for portable monitors such as wristwatches, are an extended uninterrupted monitoring period and a minimal energy consumption. In certain circumstances it may be better to use a fast processing unit having a higher power
15 dissipation if the higher energy consumption with respect to a slower unit is more than compensated by only temporary operation with intermediate inactive pauses. Besides the complete shut-off, many components such as e.g. the TMS320C5xx also offer special power saving modes. Also, the
20 reduction of the clock rate of a fast unit often allows an important reduction of the energy consumption.

Depending on the used technology, different degrees of accuracy or numbers of digits of the binary numbers may be
25 used. In tests, a sufficiently safe program recognition has been obtained with 4-bit end results. It is also conceivable, however, to effect a reduction to 3 bits, or to provide a greater number, e.g. 6 bits, 7 bits, or 8 bits. Greater numbers of binary digits are possible in particular
30 if shorter wearing times are allowed or if memories of greater capacity become available.

In the case of higher numbers of digits of the end result, it may also be necessary to increase the number of digits in

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the preceding steps to the number of digits of the end result at least.

5 Mostly, the exact values for the nonlinear mapping by table 77 as well as the threshold values for the weighting of the correlation values can only be determined empirically. Although a function similar to a logarithmization is preferred, other functions are possible. It is also conversely conceivable to emphasize the greater values in D
10 and to suppress the small values of the energy differences.

The factors and the number of digits of the convolutions may as well be chosen differently, and a different number of frequency bands into which the hearing samples are split is
15 possible. In particular, it is conceivable in the case of modified A/D conversion speeds, different settings with respect to echo and/or damping compensation, or modified hearing sample durations, to adapt low pass 59, e.g. by changing the number of tabs of the convolution.

20 It is also conceivable to perform the analog-digital conversion at a later stage of the compression, particularly if the corresponding analog circuits offer advantages with respect to the processing speed or the space consumption in
25 the monitor. In the extreme case, the digitization might be effected only immediately prior to the storage in the memory. If an analog signal is concerned, the term "digital value" in the description shall be replaced with e.g. the size or the amplitude of the signal.

30 With respect to the correlation, it is also possible to use only the part of the hearing samples which still lies within the corresponding program sample with the actual time shift t, e.g. if program and hearing samples of the same length
35 are recorded.

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An alternative of the wearing sensor consists of using currently available motion sensors. A known embodiment contains a contact which switches between the open and the closed state on motion but remains in one of the two states in the absence of motion.

Glossary

- 10 Flash RAM RAM (see there) which also conserves data in case of power failure but allows faster storage and easier erasure than classic non-volatile memories (PROM/EPROM).
- RAM read/write memory
- 15 time index number of a digital value in the succession of values leaving the digitizer (A/D converter), mostly in relation to the beginning of a hearing sample, whose associated value has the time index 0.

20

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Claims

1. Method for the compression of an electric audio signal which is produced in the process of recording the ambient
5 noise by means of an electroacoustic transducer, more particularly a microphone, wherein
 - the amplitude of said audio signal or of a derived digital or analog signal is normalized to a first predetermined
10 range D;
 - said audio signal is mapped using a nonlinear function onto a second predetermined range of values W in order to obtain an emphasis of sensitive value ranges; and
 - the result is stored in an electronic memory in a digital
15 form.
2. The method of claim 1, wherein a nonlinear function is used whose slope dW/dD decreases with increasing values in order to obtain an emphasis of the small values of said
20 first range of values.
3. The method of claim 1, wherein said result is represented by binary numbers having a fixed number of binary digits from 3 to 16 bits, preferably from 4 to 8
25 bits, and more preferably of 4 bits.
4. The method of claim 1, wherein said audio signal is divided into at least two band signals by filtering, each one of the band signals containing a frequency range of the
30 audio signal, and each band signal only containing the content of the other band signals in a clearly attenuated form, more particularly attenuated to the half, or not at all.

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5. The method of claim 4, wherein 3 to 15, preferably 4 to 10, more preferably 5 to 8, and particularly preferably 6 band signals are produced.

6. The method of claim 4, wherein said band signals essentially contain frequency ranges of the same width each, and all frequency ranges are comprised in the range of 500 Hz to 10,000 Hz.

7. The method of claim 4, wherein the band signals are generated by a single or a cascaded multiple splitting of an input signal which is the audio signal or one of the output signals in applying the following steps:

- first low pass filtering generating a first output band signal,
- subtraction of the first output band signal from the input signal for the generation of a second output band signal; all first low pass filterings preferably having the same Q-factor.

8. The method of claim 7, wherein said low pass filtering is realized by means of a digital convolution over 10 - 30 values, preferably 15 - 25 values, and more preferably 19 values.

9. The method of claim 8, wherein for the purpose of the low pass filtering, the convolution is performed with the terms $a_i \cdot x_{t-i}$, the coefficients a_i , $0 \leq i \leq 18$, being approximately equal to {0.03, 0.0, -0.05, 0.0, 0.06, 0.0, -0.11, 0.0, 0.32, 0.50, 0.32, 0.0, -0.11, 0.0, 0.06, 0.0, -0.05, 0.0, 0.03}.

10. The method of claim 7, wherein the input signal is digitized and only every nth value of each division stage is added to the band signal, n being at least 2 and preferably

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n = 2, in order to compensate for the increased data volume resulting from the splitting into band signals.

11. The method of claim 1, wherein an energy signal which
5 is proportional to the energy content is generated from said audio signal or from a signal derived therefrom, said energy signal preferably being generated by squaring.

12. The method of claim 11, wherein said energy signal is
10 subjected to a second low pass filtering.

13. The method of claim 12, wherein said second low pass
filtering is effected digitally in the form of a convolution
over 20 to 70 values, preferably 40 to 55 values, and more
15 preferably 48 values approximately, the coefficients of the convolution preferably being essentially equal to each other and more preferably equal to 1.0.

14. The method of claim 13, wherein said second low pass
20 filtering is followed by a second data reduction where one energy value among n filtered values is selected, n being at least equal to 2 and preferably equal to the number of values of the convolution of the second low pass filtering.

25 15. The method of claim 11, wherein a subsequent differentiation of the energy signal with respect to the time is effected in order to obtain an energy difference signal, said differentiation preferably being effected by
30 computing the difference between each two respective values of the signal.

16. The method of claim 1, wherein the normalization to a range of values W, which is defined by a lower limit W_u , preferably 0, and an upper limit W_o , where $W_o - W_u$ is
35 preferably equal to $2^n - 1$, n being a whole number greater

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than 4 and preferably equal to 7, is effected by:

- obtaining the maximum of the absolute value of the input signal within the normalizing duration of the signal, which is shorter or preferably equal to the duration of a hearing sample,

- by multiplying the reciprocal value of said maximum by ($W_0 - W_u + 1$), and

- by multiplying this product by each value of the input signal within the duration of the normalized signal.

17. The method of claim 1, wherein essentially all steps of the method are performed by integer or fixed point arithmetic, preferably by binary arithmetic with a number of digits as provided by the employed computing unit.

18. Device for carrying out the method of claim 1, wherein the device includes a hearing sample unit comprising at least one signal processor which memory is destined to perform at least one processing step of the method.

19. The device of claim 18, wherein a non-volatile semiconductor memory is connected to said processor which allows to store the results of the method.

20. The device of claim 18, wherein a timer is connected to the power supply of said hearing sample unit which allows to switch off the hearing sample unit when no processing activity is required, more particularly in the periods between the processing of two hearing samples, in order to reduce the energy consumption.

21. The device of claim 20, wherein the power supply of said non-volatile memory and/or said memory itself is connected to a timer in such a manner that the memory is essentially capable of being operated only during the

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storage of the results in order to reduce the energy consumption by the memory.

22. The device of claim 18, wherein it is in the form of an object which is usually carried by persons, preferably in the form of a wristwatch.

23. Method for the evaluation of the results of the hearing sample processing according to claim 1, wherein program samples of the monitored programs are recorded which have at least the same duration as the hearing samples, the program samples are subjected to the same processing steps as the hearing samples, and a calculation of a first correlation of the hearing samples with the processed program samples is effected in order to find a match.

24. The method of claim 23, wherein the recording of the program samples is started sufficiently before that of the hearing samples and its duration is sufficiently longer than that of the hearing samples to ensure that in the correlation, time shifts between the timer for the hearing samples and the timer for the program samples can be compensated by a displacement in time of the hearing samples with respect to the program samples.

25. The method of claim 23, wherein said first correlation is a standard correlation according to the formula

$$C_t = \frac{\sum_{i=1}^N (s_i m_{i-t})}{\sqrt{\sum_{i=1}^N (s_i)^2} \sqrt{\sum_{i=1}^N (m_{i-t})^2}}$$

where

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N : number of values of the hearing sample which are
 used in the correlation,
 t : time shift
 s_i : hearing sample value at the time i,
 5 m_i : program sample value at the time i,
 c_i : correlation value for the time shift t: -1 ≤ c_i ≤
 1.

26. The method of claim 24, wherein the comparison of the
 10 hearing samples with the program samples is effected in two
 passes, a respective hearing sample being compared to all
 program samples in all ways in the first pass by means of
 said first correlation whose calculation is simpler due to a
 coarser graduation of the time shift, while in the case of a
 15 time shift whose correlation values c_i are above a
 predetermined limit, a second, rugged correlation is
 effected which provides a finer graduation of the time shift
 and in particular, a time resolution which is at least twice
 as high as in the first correlation, said second correlation
 20 preferably being chosen such that great deviations between
 the hearing and the program sample have a smaller influence
 upon the correlation coefficients than in the first
 correlation, and preferably being effected according to the
 formula

25

$$r_t = \frac{\sum_{i=1}^N |s_i - a * m_{i-t}|}{\sum_{i=1}^N |s_i|}$$

where

N : number of hearing sample values used in the
 30 correlation,
 t : time shift between the hearing and the program
 sample,

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s_i : hearing sample value at the time i ,
 m_i : program sample value at the time i , and
 a : scaling factor which takes account of the damping
of the program signal with respect to the hearing
sample;
 r_t : correlation value for the shift t , 0 (optimal
correlation) $\leq r_t \leq 1$ (no correlation),
 a being determined in such a manner that r_t assumes a
minimal value.

27. Data carrier, more particularly magnetic, optical or
magneto-optical data carrier, containing a recorded program
upon whose execution the method according to claim 1 is
carried out.

28. Data carrier, more particularly magnetic, optical or
magneto-optical data carrier, containing a recorded program
upon whose execution the method according to claim 23 is
carried out.

29. Device comprising at least one program controlled
processor unit and a memory for the storage of the program
controlling said processor unit, wherein said memory
contains a program under whose control at least one and
preferably all operations of the method of claim 1 can be
performed.

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Abstract of the Disclosure

The amount of data produced in the process of recording even short hearing samples by means of a monitor (1) may be considerably reduced by effecting a normalization to a range of values D and a subsequent nonlinear mapping to a second, preferably smaller range of values W. The result may be stored in an electronic memory. Further preferred measures are the spitting of the hearing samples into e.g. 6 signals each of which contains a respective frequency band of the original signal, and the conversion of the original amplitude values into energy variation values with simultaneous low pass filtering. Preferably, all cited processing steps are performed by a signal processor (9). A continuous recording time of up to 14 days by a monitor in the form of a wristwatch can thus be attained with state-of-the-art technology.

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(Fig. 1)

UNITED STATES OF AMERICA COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION			USPTO FILE NO. P/1336-101																																																							
<p>As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named) of the subject matter which is claimed and for which a patent is sought on the invention entitled:</p> <p>Method for the Compression of Recordings of Ambient Noise, Method for the Detection of Program Elements Therein, and Device therefor</p> <p>The specification of which is attached hereto, unless the following box is checked:</p> <p><input type="checkbox"/> was filed on _____ as United States patent Application Number or PCT International patent application number _____ and was amended on _____ (if any).</p> <p>I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.</p> <p>I acknowledge the duty to disclose all information known to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.</p> <p>I hereby claim priority benefits under Title 35, United States Code §119 of any foreign application(s) for patent or inventor's certificate or United States provisional application(s) listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:</p> <p>Prior Foreign or Provisional Application(s)</p> <table border="1"> <thead> <tr> <th>COUNTRY</th> <th>APPLICATION NUMBER</th> <th>DATE OF FILING (day, month, year)</th> <th>PRIORITY CLAIMED UNDER 35 U.S.C. 119</th> </tr> </thead> <tbody> <tr> <td>Switzerland</td> <td>1997 1520/97</td> <td>23 June 1997</td> <td>YES <input checked="" type="checkbox"/> NO <input type="checkbox"/></td> </tr> <tr> <td></td> <td></td> <td></td> <td>YES <input type="checkbox"/> NO <input type="checkbox"/></td> </tr> <tr> <td></td> <td></td> <td></td> <td>YES <input type="checkbox"/> NO <input type="checkbox"/></td> </tr> </tbody> </table> <p>I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.</p> <table border="1"> <thead> <tr> <th>UNITED STATES APPLICATION NUMBER</th> <th>DATE OF FILING (day, month, year)</th> <th>STATUS (patented, pending, abandoned)</th> </tr> </thead> <tbody> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> </tbody> </table> <p>I hereby appoint customer no. 2352 OSTROLENK, FABER, GERD & SOFFEN, LLP, and the members of the firm, Marvin C. Sorten - Reg. No. 17,542; Samuel H. Weiner - Reg. No. 18,310; Jerome M. Dertiner - Reg. No. 18,653; Robert C. Faber - Reg. No. 24,322; Edward A. McIlman - Reg. No. 24,735; Stanley M. Lieberman - Reg. No. 22,400; Steven I. Weisburd - Reg. No. 11,409; Max Moskowitz - Reg. No. 30,576; Stephen A. Soffen - Reg. No. 31,063; James A. Finer - Reg. No. 30,173; William O. Gray, III - Reg. No. 30,944 and Louis C. Dujmich - Reg. No. 30,623, as attorneys with full power of substitution and reversion to prosecute this application, to transact all business in the Patent & Trademark Office connected therewith and to receive all correspondence.</p> <p>SEND CORRESPONDENCE TO: OSTROLENK, FABER, GERD & SOFFEN, LLP 1180 AVENUE OF THE AMERICAS NEW YORK, NEW YORK 10036-8403 CUSTOMER NO. 2352</p> <p>DIRECT TELEPHONE CALLS TO: (212) 382-0700</p> <p>I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.</p> <table border="1"> <tr> <td>FULL NAME OF SOLE OR FIRST INVENTOR Martin BICHSEL</td> <td>INVENTOR'S SIGNATURE <i>M. Bichsel</i></td> <td>DATE 18.6.1998</td> </tr> <tr> <td>RESIDENCE (City and either State or Foreign Country) CH-8544 Bertschikon / Switzerland</td> <td colspan="2">COUNTRY OF CITIZENSHIP Switzerland</td> </tr> <tr> <td colspan="3">POST OFFICE ADDRESS Rognisstrasse 10, CH-8544 Bertschikon / Switzerland</td> </tr> <tr> <td>FULL NAME OF SECOND JOINT INVENTOR (IF ANY)</td> <td>INVENTOR'S SIGNATURE</td> <td>DATE</td> </tr> <tr> <td>RESIDENCE (City and either State or Foreign Country)</td> <td colspan="2">COUNTRY OF CITIZENSHIP</td> </tr> <tr> <td colspan="3">POST OFFICE ADDRESS</td> </tr> <tr> <td>FULL NAME OF THIRD JOINT INVENTOR (IF ANY)</td> <td>INVENTOR'S SIGNATURE</td> <td>DATE</td> </tr> <tr> <td>RESIDENCE (City and either State or Foreign Country)</td> <td colspan="2">COUNTRY OF CITIZENSHIP</td> </tr> <tr> <td colspan="3">POST OFFICE ADDRESS</td> </tr> </table>				COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. 119	Switzerland	1997 1520/97	23 June 1997	YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>				YES <input type="checkbox"/> NO <input type="checkbox"/>				YES <input type="checkbox"/> NO <input type="checkbox"/>	UNITED STATES APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)										FULL NAME OF SOLE OR FIRST INVENTOR Martin BICHSEL	INVENTOR'S SIGNATURE <i>M. 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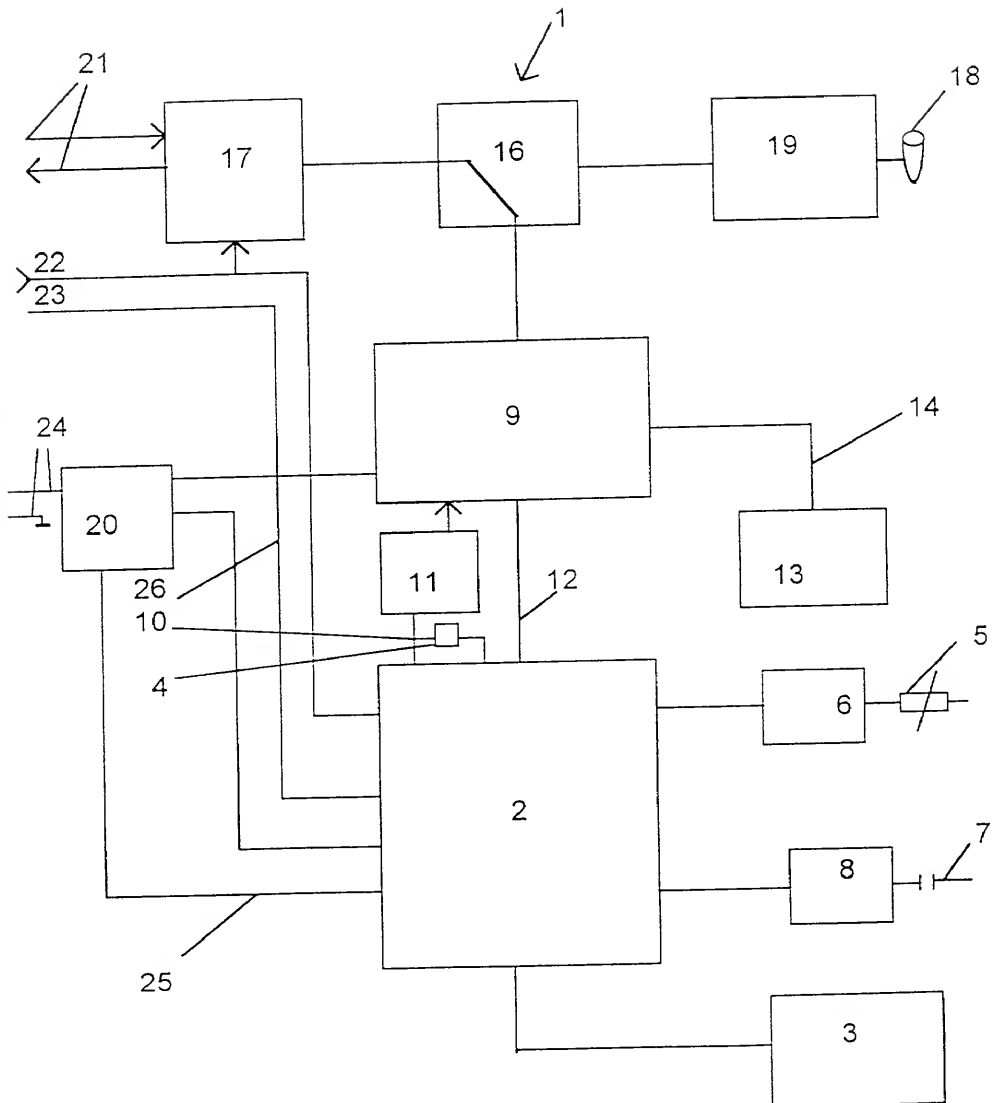


Fig. 1

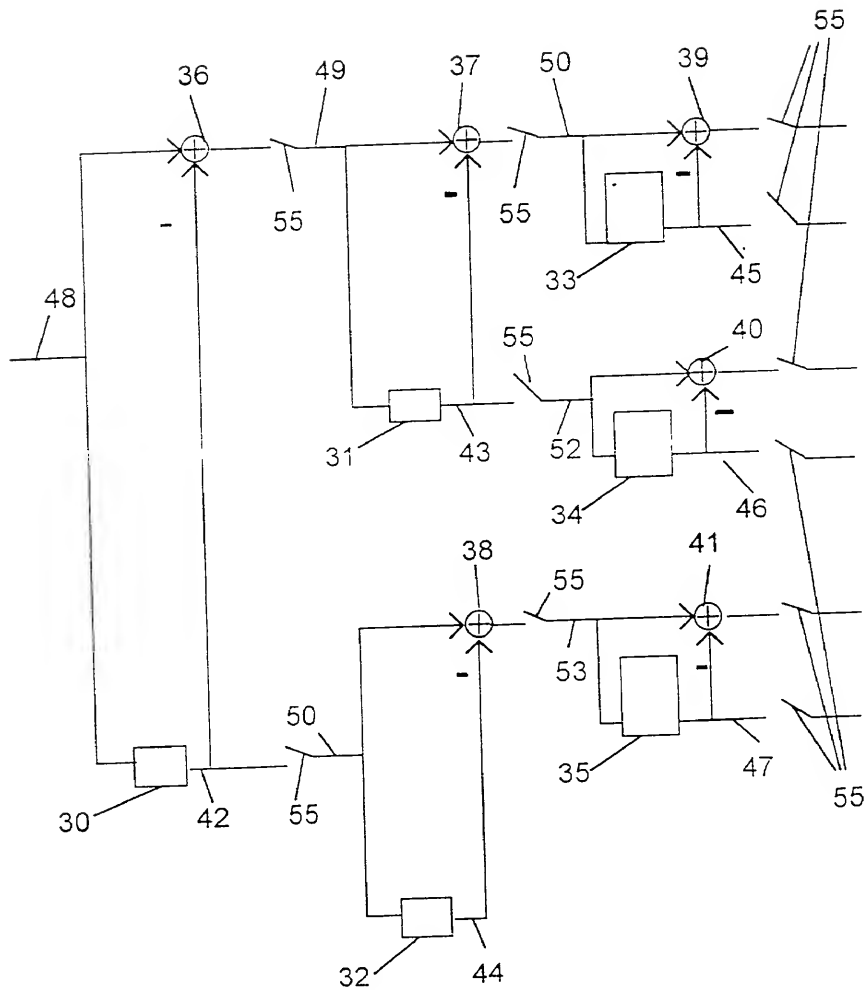


Fig. 2

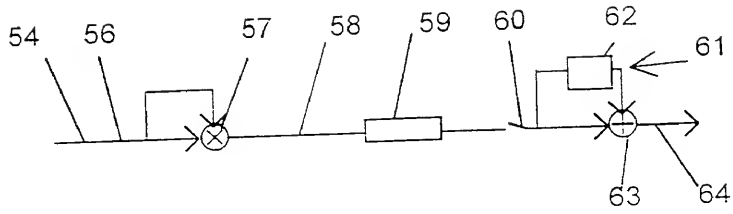


Fig. 3

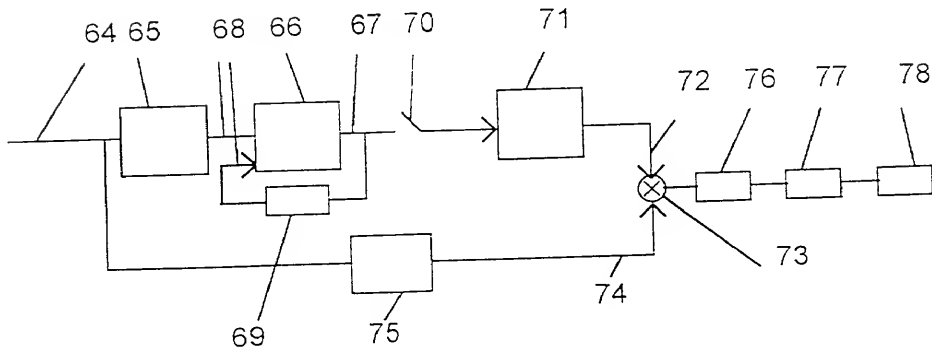


Fig. 4